Paddy drying manual

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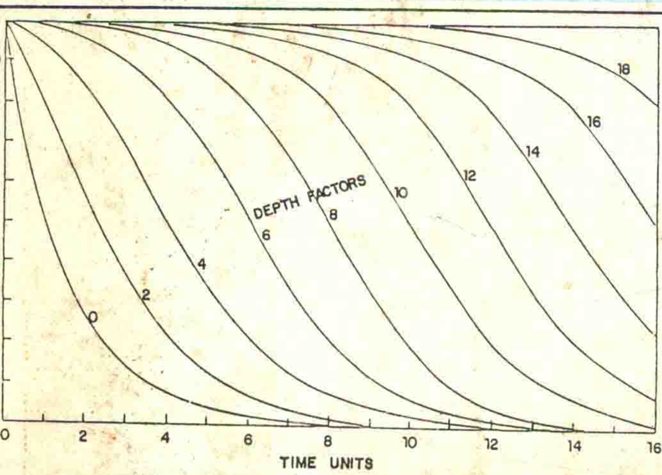

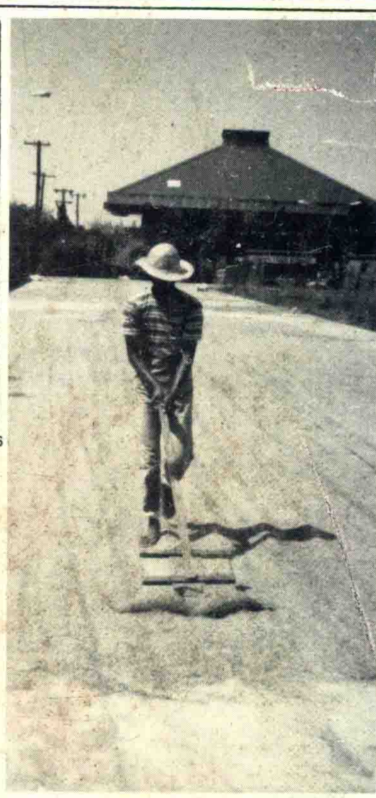

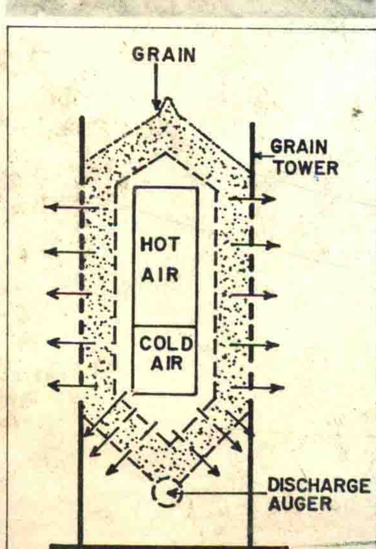

FOOD
AND
AGRICULTURE
ORGANIZATION
OF THE
UNITED NATIONS

Paddy drying manual

by
Norman Teter

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FOREWORD

Before paddy is dried, it is a perishable food commodity. It may spoil quickly, like vegetables or fruits. Drying converts paddy to a staple food that can be safely stored in order to give a continuing supply of high energy food. Paddy, in the form of milled rice, supplies the basic energy needs for nearly half the world's population. It is therefore evident that drying, as a means of rendering paddy storable and thus of preventing food loss, is an extremely important process.

Paddy drying facilities should be economically, technically and socially feasible for the market, the climate and the prevailing cropping system. A failure to meet the demands of any of these overall criteria will result in the failure of either the dryer or the whole drying system.

This manual is written for people, in tropical countries, who are involved in recommending, designing, manufacturing or operating paddy drying facilities, from the simplest drying mat to the most sophisticated continuous flow dryers of various types. Therefore, an attempt has been made to present the basic data and information needed by economists, engineers and other professionals involved in paddy drying.

The International System of Units, SI, is used throughout the manual.

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Chapter 1. INTRODUCTION

1.1. DEFINITION OF TERMS

Brokens are pieces of rice kernels smaller than "head rice". Various standards classify them into "large brokens", "small brokens" and "brewers rice" or very small brokens. Grades differ slightly as to the exact portion of the kernel falling into each category.

Brown rice is the kernel of dehusked paddy: that is, the kernel that is left after the palea and the lemma are removed. It still has the bran coat and the germ. The bran coat consisting of the pericarp, testa and aleurone layers has a brownish colour.

Cooling is the process of blowing air through the paddy, usually after drying.

Dryeration is the process of cooling after drying passes with the purpose of removing moisture as well as heat from the paddy.

Drying pass is one or more exposure periods of paddy to the drying air. The term commonly refers to systems that use several exposure periods during the drying process and the paddy is usually moved into tempering bins between the passes.

Drying time is the amount of time of exposure of the paddy to the drying air.

Fissuring is the separation of endosperm tissue in the rice kernel. It is also referrred to as cracking, checking or sometimes as breakage.

Head rice shall be the amount of whole kernels of milled rice, including 4.0 percent of broken kernels, that can be obtained by milling paddy.

Head yield is the per cent of head rice milled from paddy. This is different from percentage of head rice which refers to the ratio of head rice to milled rice.

Paddy is the matured grain of oryza sp of cereal-producing plants. It is also called rough rice.

Milling quality is a combination of head yield annd milling yield in that it refers to the amount of rice obtained from a given amount of paddy and also to the head rice that is obtained from a given amount of paddy.

Milling yield is the ratio of the rice obtained after husking and polishing as compared to the amount of paddy milled.

Moisture content is the ratio of the water in paddy to the weight of the paddy. It is given as the ratio of water to wet weight of paddy in the usual trade and this ratio is known as moisture content on the wet basis. For calculations of drying it is necessary to use the ratio of water in paddy to the dry matter weight of paddy and this ratio is known as moisture content on the dry basis. The dry basis denominator does not change in drying; the wet basis changes in drying.

Rate of drying is the weight of marketable paddy that is dried in a given time. It is usually expressed in tonnes (1000 kg) of 14% moisture content paddy dried in one hour. The drying time and the drying rate are different expressions. The rate of drying is sometimes called "throughput".

Residence time is the elapsed time between the moment that the paddy enters the dryer until the moment it exits from the dryer. The residence time in the dryer may not include the time that the paddy is held in a surge bin to feed the dryer even though that surge bin is an integral part of most continuous flow dryers.

Rice is the white endosperm left after the husk, bran coat and germ have been removed from the paddy. It is also called milled rice or white rice.

Rice husks are the palea and lemma of the paddy. They are also called rice hulls.

Tempering is a process of equilibration of moisture and temperature gradients within paddy kernels. Tempering is accomplished by holding paddy in bulk bins with either little or no ventilation for a period of 4 to 24 hours between drying passes.

1.2. PADDY DEVELOPMENT AND PRESERVATION

Plant growth depends upon the input of energy from the sun, water from the soil, carbon dioxide from the air and certain nutrients from the soil. The major part of the energy component of plants results from a synthesis called photosynthesis of water and carbon dioxide to form carbohydrates. Glucose, a molecule consisting of 6 carbon, 6 oxygen and 12 hydrogen atoms ($C_6H_{12}O_6$) may be used, with very little error, as the main component of the endosperm of paddy.

1.2.1. Paddy Growth

Among the cultivated cereal grains in all parts of the world, the rice plant is the only member of the graminasae family which thrives best in fields flooded with water. Since most of the weeds that compete with rice cannot survive in flooded soil, flooding is an excellent method of weed control and highly practical for use in humid regions having an abundance of either rainfall or irrigation water. The rice plant is also rather light sensitive, making it well adapted to areas where daylight is more or less uniform over the growing season. The humid tropics is an ideal climate for paddy growth.

The endosperm of paddy is well protected with an outer husk and an inner bran layer, whereas other cereals have the bran layer immediately exposed to permit moulds and insects to readily attack the endosperm and the germ.

Thus, paddy in several respects is an ideal tropical crop; however, its moisture content is 5 to 7 per cent above that of most cereals at the time of harvest. The nature of paddy growth makes it a cereal that must be dried.

1.2.2. Paddy Physiology

The structure of the mature paddy kernel is shown in Figure 1.1. The illustration clearly shows the multi-layer outer protection of the starchy endosperm that gives life-giving energy to many people. This starch is also food for microorganisms, insects, rodents and birds. The embryo (germ) is alive but remains dormant until the proper time exists, as regards moisture content, temperature and oxygen concentration, for it to germinate into a seedling for a new rice plant. Some high yielding varieties of rice have either a short or a nonexistant dormancy period, even though conditions other than time after harvest are favourable. Therefore, it is important that the moisture content is lowered below the level required for germination very soon after harvest, otherwise the paddy will sprout and become unfit for food.

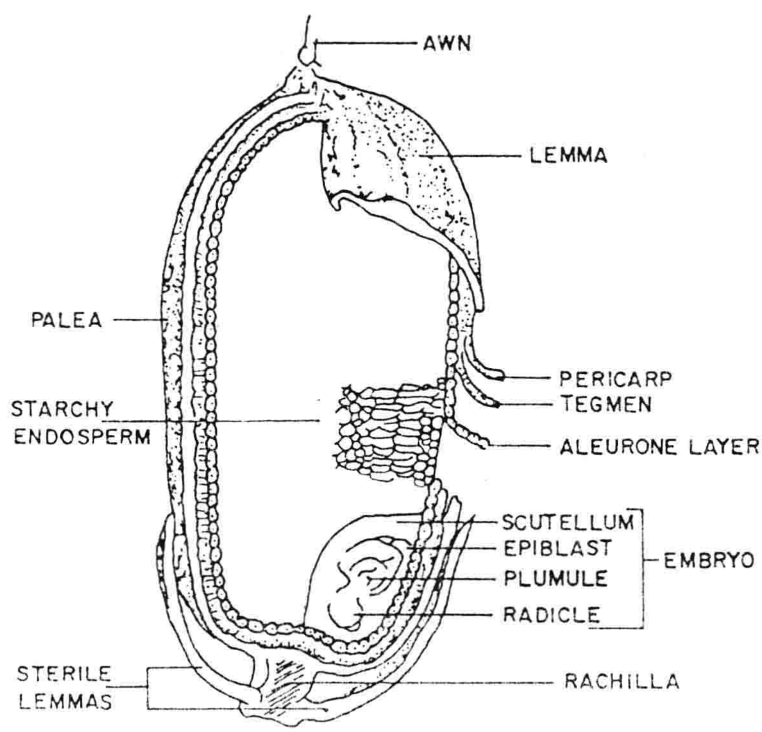

Fig. 1.1.: The structure of a paddy kernel (from Juliano and Aldama)

At maturity when paddy has 30 to 32% moisture content, the caryopsis or seed stops growing and life that is essential for reproduction of rice plants now exists in the seed through the use of stored energy in the seed. The paddy kernel changes completely at maturity from an energy, water, carbon dioxide dependent body to a physiological body that gives off energy, water and carbon dioxide.

1.2.3. Paddy Deterioration

After the seed is detached from the mother plant at harvest time it lives through a process called respiration, an oxidation process whereby the starchy endosperm combines with oxygen from the air to give off heat energy, water and carbon dioxide. The action of respiration may be illustrated by the following equation:

$$C_6H_{12}O_6+6O_2 \longrightarrow 6CO_2+6H_2O+Heat$$

Steele and Saul (83) reported that 1 gram of dry matter loss of cereal grain produced 1.47 gram of carbon dioxide, 0.6 gram of water and 15.7 kJ of heat. Seib et al (1980) confirmed these same relations of loss from paddy. When grain respires, and all grain does respire either slowly or rapidly, the moisture and heat produced must be dissipated to the outside air. This fundamental fact needs to be considered both when holding paddy before drying and tempering paddy between passes.

Dry matter loss is called deterioration, and the amount of deterioration is expressed in percent dry matter loss, %DML. The rate of deterioration is the average %DML per day, or for other time units as desired to fit the particular circumstances. Rate of deterioration is the sum of the deterioration wrought by microorganisms, insects and grain germ activity.

The six principal environmental factors of deterioration are: i) moisture content; ii) temperature; iii) the pH level of the environment; iv) innoculation of microorganisms and insects; v) the gaseous environment; and vi) the paddy variety and/or condition. Moisture content is the most important factor of deterioration; hence, use of drying to prevent deterioration and the development of toxins in cereal grains is a very important process in post-harvest operations. Deterioration rate increases exponentially with increased moisture content as shown in Figure 1.2.

Notice that paddy deteriorates at a serious rate, albeit a little less rapidly than maize. Field experience indicates that the exponential increase may become slower at moisture contents above 17%, reaching a maximum rate of deterioration at about 26% moisture where the rate is essentially constant up to 30%. These levels of moisture are extremely difficult to study in the laboratory because moulds, bacteria and actinomycetes develop so rapidly that stable conditions cannot be maintained. Moisture and temperature are interrelated in their influence on deterioration.

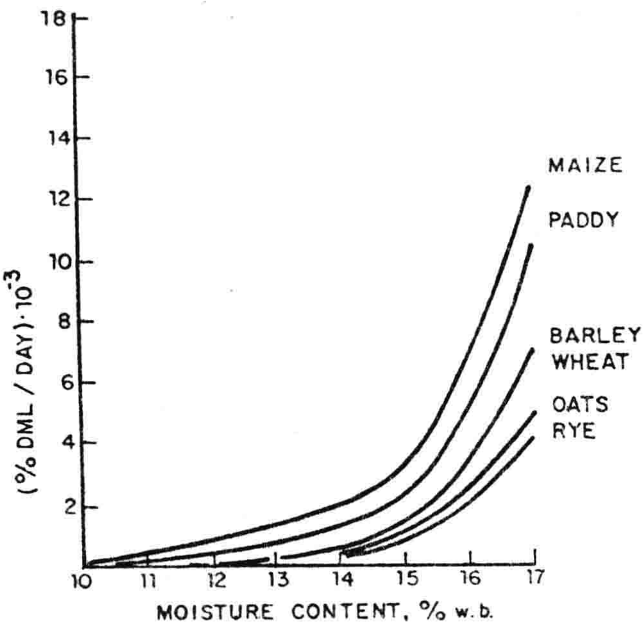

Fig. 1.2.: %DML per day at 38ºC for various cereal grains at different moisture contents (Adapted from Brookes et al, 1974)

Figures 1.3 and 1.4 show the effect of temperature, moisture content and paddy type on the rate of deterioration. Evidently, long grain with the greater surface area exposure in relation to the volume of the kernel has a considerably greater tendency to deteriorate. As temperatures rise above 45ºC the rate of deterioration will decline. Bulked wet paddy usually stabilizes at temperatures between 45ºC and 55ºC, while bulked straw and paddy often levels at 60ºC to 65ºC. Low temperatures are also very effective in decreasing the rate of deterioration because moulds are quite sensitive to temperature.
Because of the importance of temperature and humidity in their relationship to grain deterioration, each drying practice should be considered according to the climatic conditions. Recommendations made for one climatic region, such as the humid tropics, may not be applicable in another, such as the arid tropics or the temperate climate. In regions where temperatures vary from 24 to 33ºC throughout the year, deterioration from both microorganisms and insects are maximum and constant throughout the year, being mainly a function of the moisture content of the grain. Therefore, drying will be the preferred method for controlling the rate of deterioration of paddy.

Drying controls all development of bacteria or mycetes, and almost all of the development of moulds. When paddy is below 13.5% moisture content, the deterioration due to microorganisms is negligible.

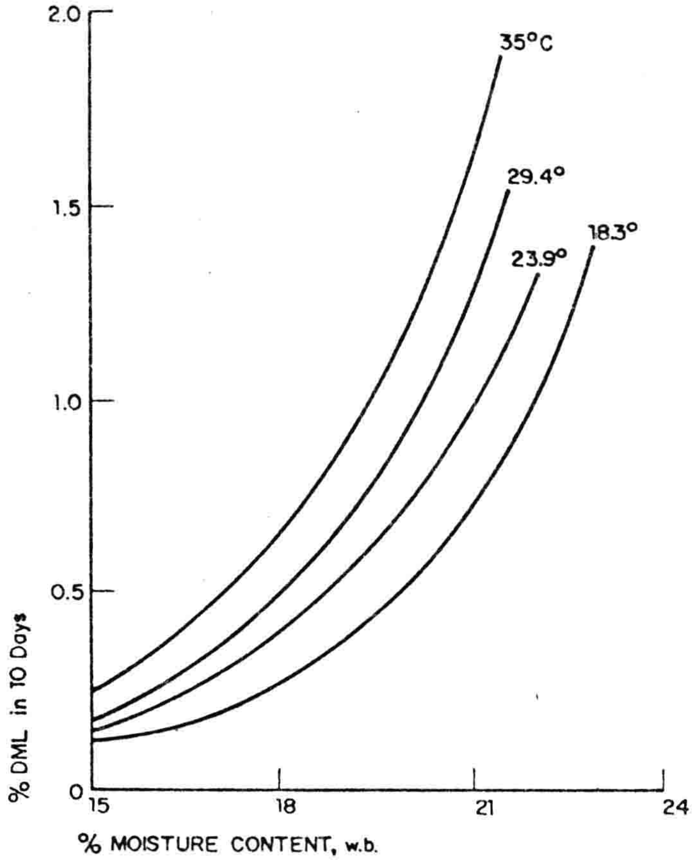

Fig. 1.3: %DML of long grain paddy in 10 days at various temperatures and moisture contents

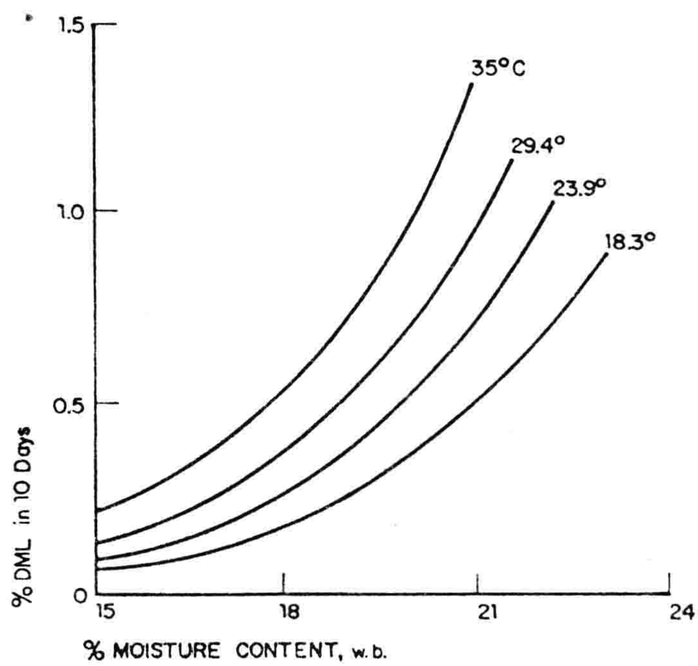

Fig. 1.4.: %DML of medium grain paddy in 10 days at various temperatures and moisture contents

Experience has shown that drying to a moisture content low enough to eliminate insects is not an economical practice. The lower limit of fungal growth in Figure 1.5 is shown at about 19% which is too high for prolonged protection from fungal growth, but it is a level of moisture that will greatly decrease the rapidity of the growth. Thus, during periods when wet paddy is being harvested rapidly, partial drying to 19% or preferably 18% moisture, and holding the paddy with ventilation through the bulk, will serve to reduce the capacity requirements of the paddy dryer.

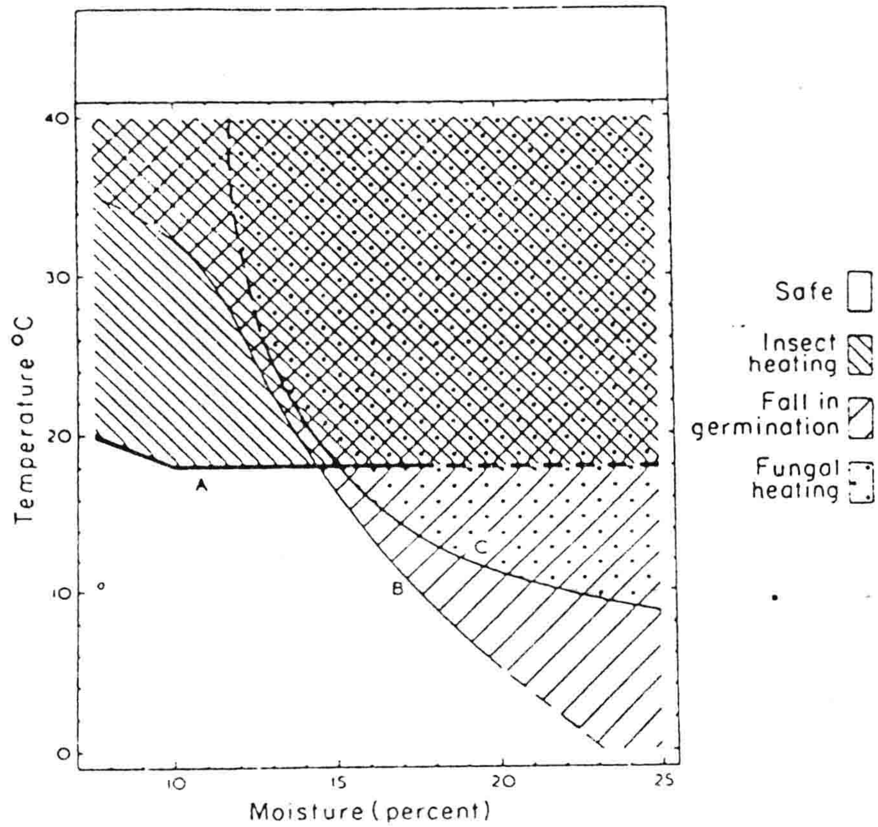

Fig. 1.5.: Values of temperature and moisture content for safe storage, insect and fungal heating, and fall in germination (D.W. Hall), 1970)

Normal or acceptable levels of deterioration are permitted in the paddy marketing systems of the world, but these levels vary with the locality and the type of marketing system. Seib (78) noted that at 18% the paddy fell in market grade if the DML exceeded 0.5%, while the 22% paddy fell in market grade when the DML exceeded 0.25%. In this study, paddy with 0.76 and 0.77% DML graded number 2. Tanganon and Jindal (85) reported that, "in continuous tests, the safe storage periods corresponded to approximately 0.65% dry matter loss in paddy samples on the basis of visual detection of discoloration, mould growth and germinated kernels". In general, the market channels of the world, either those that deal in barter or those that deal in cash, will not accept paddy with deterioration above 0.8% DML unless the cost is less than the normal market value.

Dry matter loss and discoloration are very closely associated. Both Mendoza et al (64) and Quitco and Ilag (70) showed that "yellowing" is associated with heating brought about by the combined respiration of the moulds and the paddy. Mendoza states that, "To prevent the occurrence of yellowing, harvested paddy should be immediately threshed and dried". Stacking of straw paddy should be avoided. Quitco established that fungi cause yellowing and other discolorations in paddy and milled rice.

1.2.4. Paddy Preservation

Since grain deterioration rate depends upon moisture content, temperature, presence of microorganisms and/or insects, gaseous environment, and acidity, these factors must be controlled to keep the deterioration below the acceptable level. Various techniques of grain preservation that have been widely used and some new experimental techniques are listed as follows:

a) refrigeration by either mechanical cooled air or by using naturally cold air;
b) exclusion of oxygen from the bulked grain to prevent deterioration by aerobic organisms;
c) using natural pickling of the grain by allowing lacto bacillus to increase grain acidity;
d) using chemicals to increase or decrease the pH to levels where microorganisms cannot grow;
e) drying.

Among these methods of grain preservation, drying by natural or artificial means continues to be the simplest and most practical method. Drying of paddy will therefore continue to be the principal method used for preserving rice for human food, both for technical and economical reasons, which have become even more profound in developing countries where most of the world's rice supply is both produced and consumed.

1.2.4.1. Preservation for food requires that a regular supply of sound paddy grains is preserved from one harvest season to the next, and since deterioration accumulates over time with no way of reversing the process, it is essential that newly harvested paddy be immediately dried, cleaned and maintained in a dry, clean storage. Paddy held at 24% moisture content for 24 hours gives an unacceptable food product. No drying, storage, or other process will bring the quality back. On the other hand, paddy that is immediately dried to 12% moisture content can be kept in good storage for several years and still have acceptable value. Safe storage moisture is a relative term, because other factors such as temperature of the paddy, the previous DML and mechanical damage of the paddy, the variety, the aeration practice, the insect control, and the duration of storage all influence the allowable storage moisture. In very general terms at 25 to 35ºC, paddy should be dried to 12.5 to 13.5% for storage of more than 6 months.

Since paddy has a protective coating, it stores better than either brown rice or milled rice. Brown rice has vitamins and proteins that are better food for insects than milled rice, so brown rice is the most susceptible of the three products to insect attack. Milled rice is especially susceptible to moulds which may develop in rice over 14% in moisture content. Christensen and Kaufman (32) have shown that rice stored at 14.2% moisture content and 24ºC had 20% of the kernels invaded by moulds after 45 days in storage. It is better to store paddy than to store brown rice or milled rice.

1.2.4.2 Preservation of paddy seed viability requires better drying than preservation for food. For a high yielding variety of paddy that has little or no dormancy after harvest, the grain may sprout before it is dried. Sprouted paddy not only ruins the future use as seed, but also damages the paddy as potential food. Viability of wet paddy decreases rapidly in time compared to viability decreases in dry paddy. The number of weeks for 50% germination being lost is estimated by Roberts (75) to be:

$$N = 10^{(5.686 - 0.069\,T - 0.159\,M)} \qquad (1.1)$$

where T = temperature, ºC;
M = moisture content, % w.b.
and N is the estimated number of weeks for 50% germination being lost.

Table 1.1 shows the effect of temperature and moisture content on the loss of viability as computed from this equation.

Table 1.1: Estimated weeks for paddy to lose 50% germination at various temperatures and moisture contents.

	Temperature, ºC						
%M.C.	20	22	24	26	28	30	32
12	250.0	182.0	132.0	96.0	70.0	51.0	37.0
14	120.0	87.0	64.0	46.0	34.0	25.0	18.0
16	58.0	42.0	31.0	22.0	16.0	12.0	9.0
18	28.0	20.0	15.0	11.0	8.0	5.7	4.1
20	13.0	10.0	7.0	5.2	3.7	2.7	2.0
22	6.0	4.7	3.4	2.5	1.8	1.3	1.0
24	3.1	2.2	1.6	1.2	0.9	0.6	0.5

If the temperature averages 26ºC, paddy with a moisture content of 12% should maintain satisfactory viability for a year; whereas paddy with 22% moisture content would be unsatisfactory for seed after about a week. Moisture content has a profound effect on viability, so drying seed well is especially important to avoid losses. If seed is to be stored for more than a year, the moisture should be reduced to 10% and kept at that level during the storage life.